# The Application of Lean Manufacturing in a Mining Environment

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## ABSTRACT

This paper examines the application of Lean Manufacturing in a mining environment, based on experience within the Rio Tinto entities: Rio Tinto Aluminium, Northparkes Mines and Hunter Valley Operations.

The three applications have tested the flexibility of the Lean methodology.

Within Rio Tinto, Rio Tinto Aluminium was the first group to introduce Lean. The rollout began in late 2004. It was introduced firstly at Boyne Smelters, Gladstone, as a model site with the initial application in the Carbon Bake Furnace area. It was later extended to other sites including the Weipa Bauxite Mine.

Lean's successful application within Rio Tinto Aluminium was in part responsible for its recent adoption by other Australian-based Rio Tinto business units including Northparkes Mines, a copper mining operation in Central New South Wales, and Hunter Valley Operations, a group of four coal mines in the Hunter Valley region of New South Wales.

Lean is also being adopted by Rio Tinto Iron Ore.

Rio Tinto Aluminium introduced Lean Manufacturing to complement an existing Six Sigma business improvement program and to achieve continuous improvement activities at a workplace level.

Lean provides a similar level of rigour and discipline to Six Sigma but its application is everyday and for everyone, everywhere in the workplace. It is a valuable management tool. In a short time, Lean has achieved good and sometimes spectacular results improving productivity and efficiency at all sites, including our mining site.

Within Rio Tinto Aluminium, it has also had beneficial impacts on our ability to develop and retain employees.

## INTRODUCTION

Lean Manufacturing is the preferred workplace business improvement methodology of many manufacturing and processing industries around the world.

Lean evolved from Henry Ford's earliest efforts of mass production in the vehicle industry. Its modern roots are in the production system developed by Toyota from the 1950s, initially for its vehicle assembly lines and later extended to other aspects of its business.

The Toyota Production System contributed to the rise of Toyota as one of the most successful automotive businesses in the world.

What differentiates Toyota from its competitors, according to Harvard Business School Professor Steven Spear, is that Toyota and its best suppliers 'can confidently distribute a tremendous amount of responsibility to the people who actually do the work, from the most senior, experienced member of the organisation to the most junior. This is accomplished because of the tremendous emphasis on teaching everyone how to be a skilful problem solver.'

'Problems', in Spear's and Toyota's world, are sources of waste and frustration, where performance does not measure up to expectation.

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The connection of Lean to Toyota and other vehicle manufacturers, along with the implicit link to manufacturing contained in the formal title Lean Manufacturing, firmly associated Lean with that industry sector.

Some may spot potential pitfalls in applying a system designed for the automotive industry to a resource and minerals processing business such as ours. Defining those differences is an exercise that we ourselves undertook (see Table 1).

**TABLE 1**

*Comparisons between resource/minerals businesses and automotive operations.*

| Resource and minerals business | Automotive business |
|---|---|
| A smelter or refinery cannot be stopped so there is inherent production push in the process | An automotive assembly line can be stopped so there is the ability to create pull systems |
| Production is in continuous units and around the clock | Production is in discrete units and often on less than one day cycles |
| Generates considerable dust | Little dust |
| Physically challenging environment | Ambient conditions |
| Inherently variable environment | Stable work environment |
| Remote locations | Large centres |
| Impact of weather | Indoor environment |
| Inherently variable raw materials | Controlled raw materials |
| Geographically spread output teams | Compact plants |
| Molten metal has a short shelf life before it solidifies | Long-life components suitable for supermarket-style storage |

Nothing inherent in Lean is specific to discrete manufacturing processes and, in recent years, it has become a common and effective methodology in many other manufacturing, processing and service industries.

A formal definition might be: Lean is the ceaseless elimination of waste.

In practice, Lean relies on:

- engaging workplace leaders;
- asking employees to set agreed standards for their work;
- empowering employees to write their own standards and improve them;
- the visual representation of key production performance data, empowering employees at the lowest level to make operational decisions based on data;
- forming operations and maintenance employees into manufacturing teams; and
- application of a suite of business improvement tools.

Managers must make the unnerving leap of allowing shop floor personnel to solve problems and make operational decisions. The manager's ongoing role is to be an equal contributor and a mentor who will clear obstacles to progress, providing necessary resources and challenging the team to continually improve. Managers should also coach problem-solving.

Nothing in the above definition appears to preclude Lean's application to a minerals processing business or, indeed, to a mining operation.

When Rio Tinto Aluminium (RTA) made the decision to take on Lean, we were aware that other leading aluminium businesses had successfully applied Lean techniques to mining, refining and smelting.

Within the Rio Tinto Group there is structured collaboration and, thus, it followed that the successful application of a business improvement technique in one business unit would lead to its adoption by others.

Northparkes Mines (Central New South Wales) and Hunter Valley Operations (Hunter Valley, New South Wales) have since found applications for Lean methodology at their respective operations.

Russell Sanford, who is Team Leader (Processing) for Rio Tinto's Improving performance Together (IPT) program, is convinced that Lean is as effective in a mining environment as in a manufacturing one.

Russell has led efforts to institute Lean Information Centres at the Hunter Valley Operations mines.

He concludes that:

> *While there was initial resistance on the grounds that 'mines are different to Toyota', there has since been rapid acceptance that the Lean philosophy adds value and is consistent with the basic mining process.*

Barry Lavin, Managing Director of Northparkes Mines, while of the view that mining is a vastly different environment to manufacturing, nevertheless sees applications for Lean within the mining process.

At Northparkes Mines, Lean was applied to the process of tunnel development in a new underground mine. Barry notes that the development process is sequential, with each step to be completed before the next may be undertaken. 'In this regard,' he says, 'it is similar to manufacturing, where a series of processes lead to a product.'

Barry says this was a factor when considering whether to use Lean tools on the job.

## RIO TINTO ALUMINIUM'S BUSINESS IMPROVEMENT JOURNEY

*Keith Dunstan, General Manager, Comalco Business Improvement*

Rio Tinto Aluminium's business improvement journey began with the demise of what our Managing Director Smelting NZ/UK, Tom Campbell, refers to as the fat and happy days of the early 1990s.

He recalls:

> *The years that followed were not pleasant: facing the next price cycle low, the organisation simply had no alternative but to slash costs through a bitter pill we called PEP, for Performance Enhancement Program.*

PEP was unsophisticated – anything not essential to core processes was cut and, sometimes, muscle rather than fat was cut.

> *The program was necessary to bring us back from the brink but – ask anyone who was there – it was stressful.*

Campbell believes the major lesson of PEP was that once the easy cost savings were made, a highly structured approach to business improvement was required.

**TABLE 2**

*Rio Tinto Aluminium's Assets. (Rio Tinto Aluminium is a wholly-owned subsidiary of Rio Tinto and is a leading supplier of bauxite, alumina and aluminium.)*

| Industry | Asset | Stake |
|---|---|---|
| Bauxite mines | Weipa, Far North Queensland, Australia | 100% |
| Alumina refineries | Comalco Alumina Refinery, Gladstone, Queensland, Australia | 100% |
| | Queensland Alumina Limited, Gladstone, Queensland, Australia, | 39%† |
| | Eurallumina, Sardinia, Italy | 56%† |
| Power | Gladstone Power Station, Queensland, Australia | 42% |
| Aluminium smelters | Bell Bay, Tasmania, Australia | 100% |
| | Boyne Smelters Limited, Gladstone, Queensland, Australia | 59% |
| | New Zealand Aluminium Smelters Limited, Tiwai Point, New Zealand | 79% |
| | Anglesey, Wales, UK | 51% |
| Corporate | Comalco Aluminium Limited, Brisbane, Queensland, Australia | |
| | Comalco New Zealand Limited, Wellington, New Zealand | |
| | Comalco Sales Office – Beijing, China | |
| | Comalco Sales Office – Tokyo, Japan | |
| Research | Comalco Research and Technical Support, Melbourne, Victoria, Australia | |

† Non-RTA managed sites.

At this time we introduced a DuPont Safety Program that focused the organisation on health and safety and produced dividends both for safety and the bottom line.

The organisation subsequently introduced an Annual Action Planning process, an In Control Then Capable (ICTC) program (which took an in-depth look at process management focusing on reducing process variation) and, after searching the world, Six Sigma and later Lean.

Each of these steps incrementally increased our capability for improvement (see Figure 1).

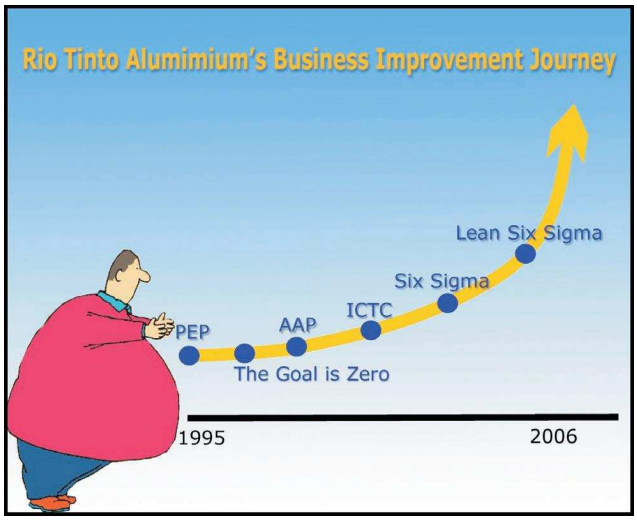


FIG 1 - RTA's business improvement journey began in the mid-1990s.

Six Sigma is project-based and can leverage gains by finding the root causes of process variations and fixing them. Since 2003 RTA has achieved improvements valued at around A$25 million each year from Six Sigma projects.

Since 2002, we have systematically trained over 350 people within the company as project leaders known, in the language of Six Sigma, as black belts, green belts and yellow belts.

Our annual planning system identifies projects that can add major value through saving costs, increasing capacity or which have important safety or environmental dividends. Project leaders implement these improvements.

Six Sigma played an important conditioning role within RTA for the later adoption of Lean. It created a data-based problem-solving culture; all managers and superintendents and most crew leaders are familiar with Six Sigma's phased approach of define, measure, analyse, improve, control.

Six Sigma changed emphasis within the group from rewarding and revering fire-fighters – people who could respond to crises and fix things – to focus on pre-emptive measures: being in control of our processes and identifying potential problems and improvement opportunities.

Lean was chosen as RTA's vehicle for extending business improvement to the workplace.

Its objective would be to achieve daily incremental improvements at an operational level on an ongoing basis, engaging everyone in the process.

## The application of Lean within RTA

In late 2004, RTA took on UK-based consultant LMR (Lean Manufacturing Resources) to assist with implementation.

LMR's key personnel come from a Toyota Production System background and were closely identified with the development and implementation of Lean at Toyota and other automotive companies.

We decided to select a model plant within RTA to begin the implementation and, once it was on its feet there and our own people began to understand the system, we would broaden it to the rest of the company. The model plant would provide a training ground and a showcase for the rest of RTA.

The complete Lean system can be visualised in a structure known as The Lean Temple (Figure 2).

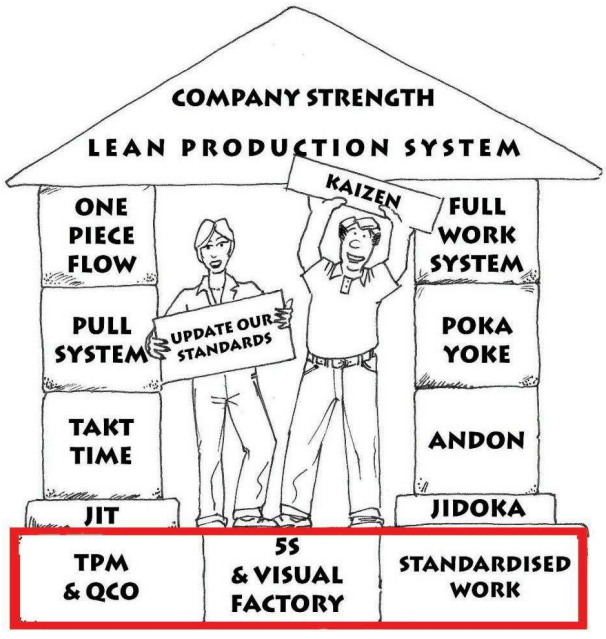


FIG 2 - The Lean Temple.

The three blocks at the bottom of the temple outlined in red are known as Foundation Elements.

Our objective is to implement examples of all the Foundation Elements into every site by mid-2007.

Our experience with Six Sigma demonstrated to us the importance of taking a strategic, company-wide approach to business improvement if we were to achieve sustainable cultural change across the organisation.

The advice from LMR and our own inclination was to take a similar approach with Lean: we would not confine it to areas within our facilities that most resembled manufacturing operations; rather we would commit to its implementation in all areas at all sites, including our mining operations.

The strong view of our leadership team was that to create a culture of continuous improvement within RTA, Lean and Six Sigma had to become fundamental to the way we worked.

This implied that 'Lean Six Sigma', as we chose to brand it, should be directed at all employees.

## The Carbon Bake Furnace experience

The first application at the model site was the Carbon Bake Furnace at our largest aluminium plant, Boyne Smelters at Gladstone, in Central Queensland.

It was a continuous production line process that would lend itself to the conventional application of Lean and it had a history of intractable process problems that had defeated attempts to fix them.

Boyne Smelters' Manager Carbon, Joe Rea, says the problems stemmed from a major process change that required more carbon anodes to be made for the alumina reduction process in a shorter time.

Rea recalls:

> *What happened was that anode quality suffered and, as a result, there were performance issues on the Reduction Lines arising from those quality issues. It was fair to say that the processes that we had in place weren't the best to get our operations and maintenance practices in synch.*

Rea and other managers would quickly learn that underpinning the Lean philosophy was a requirement to empower employees to solve problems and, thus, make decisions relating to production.

This was not without precedent within the company. Our DuPont-based safety program, The Goal Is Zero, begun in the late 1990s, required us to empower employees not to carry out a task if they considered that it was potentially unsafe. The slogan used was: 'if it's not safe don't do it that way'.

The program proved to be extremely successful at instilling a methodical, zero injuries approach to work among all employees that exists to this day.

In this respect, Lean is similar to The Goal is Zero in that it empowers people – in this case to recognise and eliminate waste.

Initially, Rea continued to run traditional daily production meetings in parallel with the manufacturing meetings that the Lean team set up in a new Lean Information Centre in the Carbon Bake unit.

It rapidly became apparent that the old production meetings were redundant.

The figures being captured on the walls of the Information Centre created a real-time view of production performance and, importantly, the 15-minute daily manufacturing meetings brought together operators, maintainers and contractors to cooperatively solve problems and address issues as they arose.

Rea recalls that within six months, previously intractable issues had been quietly resolved and the Carbon Bake Furnace was, for the first time, ahead of schedule.

*Progress has been excellent. There is a predictability about our process that comes only from being in control. The implementation of Lean has basically brought that to us.*

## Information centres

Ron Jorgensen is Superintendent in charge of the Carbon Bake Furnace at Boyne Smelters. He had previous Lean experience and is a passionate advocate of it.

He set up the initial Lean Information Centre at Boyne Smelters, establishing a benchmark that would be used in all other Information Centres throughout RTA as the Lean rollout progressed.

He notes that the metrics chosen to gauge the progress of production and pinned on the wall came from suggestions made by operators and crew leaders.

*To some degree, before Lean came in we used to get into analysis paralysis,* he reflects. *We used to have charts upon charts upon charts and at the end of the day people just got lost in the detail. So we took a step back and said: what are the six key metrics that we need to look at on a daily basis that make sense?*

The metrics align to the six pillars of RTA's corporate strategic map: health and safety, people commitment, environment and communities, market position, operational excellence and, financial strength.

Generally the metrics are displayed either in graph form or in Lean's green cross format – a diagram which documents each day of the month and to which a colour is assigned – red, blue or green – indicating, respectively, a setback, status quo or an improvement for each shift of each day (see Figure 3).

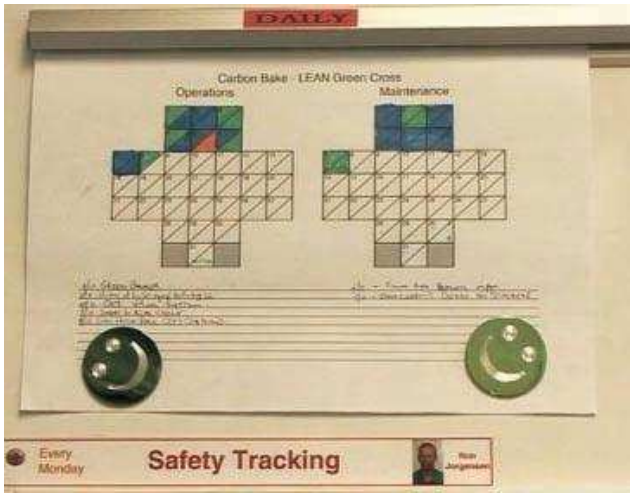


FIG 3 - A green cross sheet.

Information Centres also typically contain:

- a master schedule, detailing and tracking the Lean implementation schedule;
- a detailed value stream map of the production process identifying points at which value is added or lost; and
- concern, containment and countermeasure strips that identify and track issues and their resolution.

Information centres are located centrally within workplaces so that everyone has access to them.

Crew leaders and superintendents ensure that metrics in the centres are updated daily.

## The Foundation elements

An outline of Lean's Foundation elements is appropriate to give readers an appreciation of how Lean attacks waste and effects workplace change.

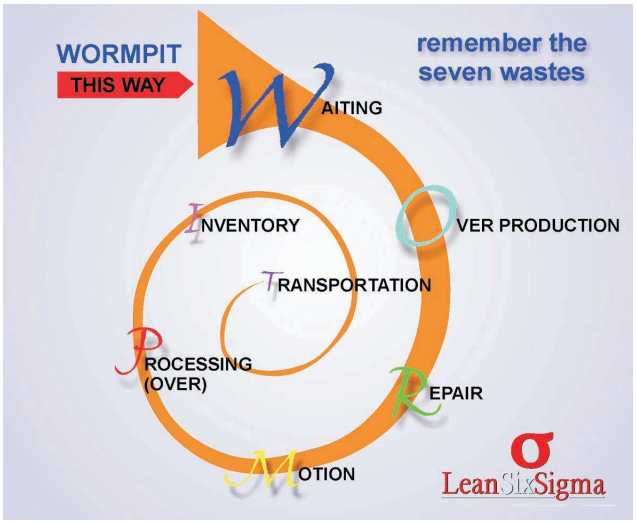


FIG 4 - Lean methodology defines seven types of waste known by the acronym WORMPIT.

### *5S and Visual Factory*

The central Lean Foundation Element is '5S and Visual Factory', which concerns the cleanliness, organisation and accessibility of workplaces.

Lean methodology makes production and maintenance performance visual so that, when one enters a workplace, simple visual cues on the walls or adjacent to equipment show at a glance how things are progressing.

Getting the workplace organised is the role of 5S (for sort, set, shine, standardise and sustain).

When 5S was first introduced to the Carbon Bake unit the universal conclusion was that 'we are going to have a bit of a clean up'.

More than 50 tonnes of gear was collected and disposed of but, in fact, that was only the first part of the job (see Figure 5).

FIG 5 - Some of more than 50 tonnes of gear collected and disposed of from the Carbon Bake Furnace work area.

Fundamentally, 5S is about organising and visualising the workplace so that tools and equipment are located close to where they are needed. It is an ongoing activity.

The visual factory includes kamishibai boards – boards containing double-sided cards that immediately show whether a scheduled task has been carried out (green side showing for yes, red side showing for no) (see Figure 6).


FIG 6 - (**A**) A kamishibai board; and (**B**) a single point lesson attached to equipment.

It also includes single point lessons: an A4 page in a standardised format that demonstrates the correct operation of the piece of equipment it is attached to.

In the Carbon Bake area, almost two years on, everything has a well defined place using shadow boards or other types of demarcation that allow quick audit by exception. It is obvious if a tool or bit of gear is not where it should be (see Figure 7).

FIG 7 - A shadow board at Boyne Smelters' fabrication workshop.

Nothing is present in the workplace that should not be there; there is much less dust and ash; and, what used to resemble one of William Blake's 'dark satanic mills' is an orderly, safe and pleasant workplace.

The fiercest advocates of the new order often include those who initially put up most resistance to the change.

## *TPM and QCO*

TPM stands for Total Productive Maintenance. At its heart is a philosophy of bringing maintainers and operational employees together to work out how to improve the overall effectiveness of equipment (OEE).

The aim is to achieve the ideal state of zero equipment breakdowns, where operators perform routine maintenance (called autonomous maintenance) and maintainers conduct scheduled maintenance to keep the equipment permanently in good working order.

The process begins with a deep clean designed to return the equipment to its original state, followed by identification and elimination of sources of contamination (such as fixing or containing fluid leaks).

Work processes are standardised and equipment is tagged with Single Point Lesson sheets, which identify routine checks necessary to ensure that the equipment is in good order and being used properly.

The process is sustained through a structured training program and operational employees are encouraged to 'own' pieces of equipment.

QCO refers to quick changeover and relates to events where production must be stopped to effect an operational change or scheduled maintenance.

The process identifies elements of the changeover and sorts them into those which are done with production equipment operating (external) and those which are done with the equipment stopped (internal).

The process is analysed to convert as many internal tasks to external ones as possible, progressively shortening production downtime.

## *Standardised work*

Standardised work is a rigorous procedure to standardise, document and progressively improve the way work is done and is applicable to all the other Lean tools.

It is implemented through discussing existing practices for a particular work process and documenting a baseline procedure. Through 'kaizen' or brainstorming sessions or through suggestions made by employees at regular manufacturing meetings, the procedure is incrementally improved.

A revelation for most people is that the process of implementing a baseline procedure, which is then used by everyone who does the job, immediately makes the process measurable. What follows is a creative process to improve it.

The payoff from all of the Lean Foundation Elements is the progressive freeing up of people's time. Frustrating, stressful workplaces become pleasant environments where the main preoccupation is finding new ways to improve things. Opportunities are created for people to learn and develop skills.

## *Advanced Lean tools*

Once the Foundation Elements have been implemented, RTA will employ the advanced Lean elements that make up the pillars of the Lean Temple known as Jidoka and JIT (see Figure 1).

Jidoka means quality and the Jidoka tools embody a philosophy of not passing on products that do not meet customer specifications.

JIT is for Just In Time and the tools it uses focus on making the right amount of good product at the time when it is needed.

## Results

All of Lean's Foundation Elements have been implemented within the model Carbon Bake site at Boyne Smelters. They are progressively being implemented at all other RTA sites.

Perhaps the most surprising and impressive thing about RTA's Lean journey is how quickly change can be effected. At the model site, a palpable shift in attitudes of people towards their work and workplace was evident within weeks.

This has been repeated at other sites and there is much enthusiasm for Lean.

RTA is at the early stages. As should be obvious from the above discussion, Lean is a way of working and, thus, a never-ending pursuit.

Lean has integrated extremely well with our Six Sigma project work. In most cases Lean techniques have been used in the control phase of Six Sigma projects to lock in major improvements.

Likewise, a number of Lean activities have identified Six Sigma projects which have subsequently liberated high value. In other cases, Six Sigma methodology has assisted more complex Lean implementations.

Lean Six Sigma has had an impact on RTA's ability to retain people. Human Resources tracking over the past year has shown an improvement in our employee retention in the model site area, some of this attributable to Lean.

By taking a strategic, whole of company approach, Lean Six Sigma has an organisational structure within RTA and we are thus able to define and offer career paths to employees. This is valued by employees and it has increased the worth of the organisation, as evidenced by our financial and other results.

## Carbon Bake Furnace results

Following a prolonged period of process instability the Carbon Bake Furnace very quickly achieved stability with the application of Lean.

Within months of implementation, key performance measures all showed improvement, which we believe are largely due to Lean (see Table 3).

To September 2006, improved performance in carbon quality has been sustained as measured by anode reactivity and the amount of carbon dust present in Reduction Line cells (see Figures 8 and 9).

## Application of Lean at the Weipa Bauxite Mine

All work areas at Weipa have Information Centres and all are implementing the Foundation Elements.

Weipa has a resident LMR consultant, Lean coaches and advisers drawn from our Business Improvement unit and elsewhere in the organisation.

The two Lean coaches, five Lean advisers and many of the managers at Weipa have all, at minimum, experienced Lean at Boyne Smelters through a week-long Lean Immersion training program.

One Lean coach is assigned to each functional division (we call them MRUs for Mutual Recognition Units) at Weipa.

The strategy used for the Weipa rollout, begun in quarter four 2005, was to initially establish Information Centres site-wide at an output team (production) level.

Within three months, 31 centres had been created, including non-manufacturing areas such as stores, the training area and human resources.

Weipa's Manager Business Improvement, Gillian Croft, says the focus is on creating a visual factory so employees can clearly assess situations and act on them.

> *As a priority we are standardising key business indicators across the site and aligning them with the pillars of RTA's corporate strategic plan.*

Lean gives employees access to production data that, in most cases, were not previously available in an accessible form.

Ultimately, in any work area employees will be able to see and comprehend how the output teams are performing.

At the Weipa site, for the mining application, Lean's seven wastes have been interpreted thus:

- waiting – eg trucks may be waiting at an excavator or dump site;
- over-production – eg mining capacity may outstrip the plant's ability to process ore;
- repair or rework – eg having to fix trucks after oil overfills;
- motion – eg operators may have to walk a long way for crib breaks, or to hand over;
- processing (over) – eg processing ore to a better grade than the customer is willing to pay;
- inventory – eg keeping either excess or too little inventory on site; and,
- transportation – eg moving mined ore many times before it reaches its final destination.

**TABLE 3**

*2004 - 2006 year-to-date (annualised) achievements in the Carbon Bake Furnace.*

| | | | | |
|---|---|---|---|---|
| Health and safety | Incidents<br>154 ↘ 67 | First aid<br>24 ↘ 0 | Lost work days<br>1 ↘ 0 | Medical treatment<br>1 ↘ 0 |
| People commitment | Turnover<br>15.5% ↘ 9% | Absenteeism<br>3.4% ↘ 1.8% | | |
| Environment and communities | Odours<br>14 ↘ 2 | | | |
| Market position (internal customer quality measures) | Conformance to heating curve<br>70% ↘ 88% | Anode rejects<br>2% ↘ 0.9% | Unscheduled changes<br>60 p/day ↘ 8 p/day | |
| Operational excellence | Carbon dust<br>20% ↘ 6% | Net carbon ratio<br>0.431 ↘ 0.410 | | |
| Financial strength | Recycled >200 t coke valued at $386 867.<br>New in-house coke screen saves $130 000 pa | | A$2 million annualised savings. A$1.9 million gain from avoidance of additional fan capacity.<br>Delay of $1.2 million furnace re-build. | |

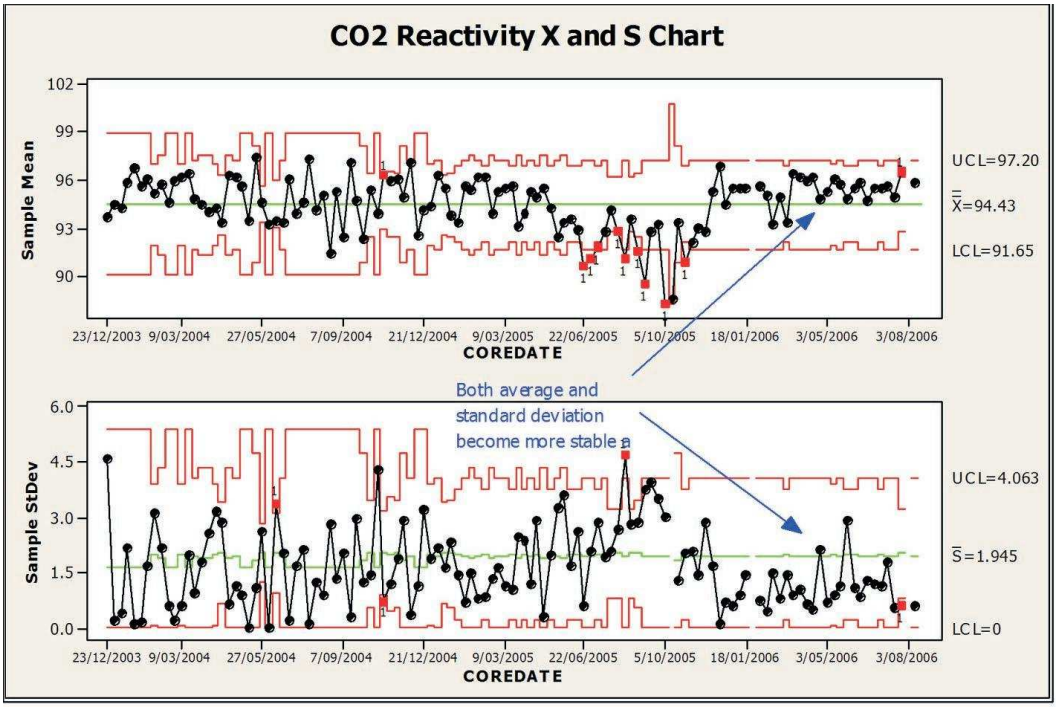


FIG 8 - Anode quality metric: average and standard deviation are more stable.

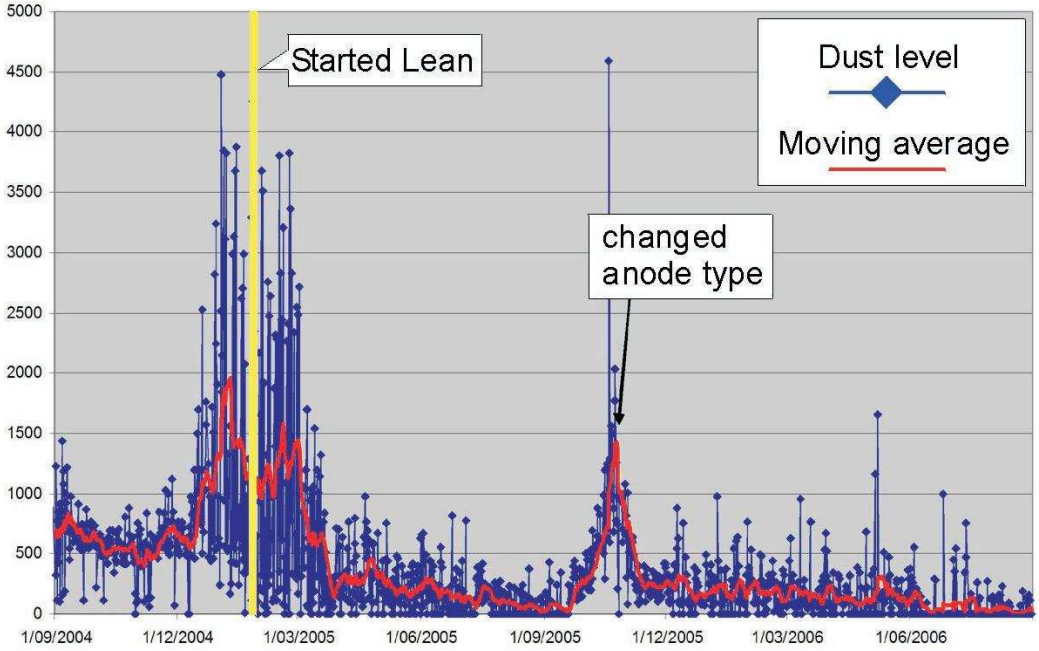


FIG 9 - Carbon dust levels in cells in Reduction Lines 1 and 2.

The rollout of 5S across the site initially focused on 'difficult' areas where facilities were old and/or where ongoing production difficulties had been experienced.

These included the calcination plant (where bauxite ore is baked to remove moisture) and the railway workshops that service the rail loop between mining sites and the export port.

> *The initial aims were relatively modest,'* Croft reflects. *We wanted to make a visible difference and show that 5S could be employed as a value-adding tool anywhere – not just in indoor, controlled environments.*

The rollout of Standardised Work began in quarter one, 2006 by identifying opportunities site-wide.

At the Andoom mine's truck service bay it combined with a Six Sigma project to improve the turnaround time for servicing haul trucks, as this was considered to be a complex and valuable project (see Figure 10).

Six Sigma Black Belt, Simon Kaufman, worked with the output teams to analyse truck and people movements.

By challenging the routes people used and the layout of hose reels and other equipment, they were able to significantly reduce the time taken for routine services – refuelling, topping up oil and checking tyre pressures.


FIG 10 - Before and after pictures of the Andoom truck service bay demonstrate the impact of a deep clean.

Kaufman says that based on present progress, the work will increase productivity by at least one truck load over the crude ore dump per day, equating to 195 wet crude tonnes. Over a year, for the Andoom mine site this will save over 40 000 dry product tonnes (around A$350 000).

The changes were documented by the output teams using Lean Work Element Sheets (one of the Standardised Work tools) that describe procedures, list helpful hints about tasks and visually show key physical features of those tasks.

Among the benefits of the standardised procedures have been a reduction in contamination of lubricants and oils by capping nozzles and cleaning fill points and the introduction of a Standardised Work procedure aimed to reduce the incidence of overfilling engine oil levels in the haul trucks during top-ups.

Data gathered by Kaufman and William Seal, the Andoom Lean Adviser, showed that this occurred twice a month on average and caused at least two hours lost production valued at A$28 000 per year.

Another innovation was to standardise the location where trucks were parked. This will reduce cycle times once tools are moved to their ideal locations.

Kaufman videotaped the new service procedure and this is now used in training mine operators.

He says the standardisation involved simple measures – visually clarifying which dipstick mark to fill to and getting operators to check the level after every addition of ten litres of oil.

Croft notes that the simplicity of Lean solutions is a key feature.

> *The tools provide output teams with what they need to get organised and the solutions are then generally very simple.*

TPM has yet to be implemented at Weipa. QCO is being managed on a project basis with opportunities being identified, prioritised and then developed.

Croft says that hand in hand with the bottom up application of Lean, a top down training program has been used.

To date 146 employees have received a two-day Lean introduction training course including the general manager operations and nine area managers.

One contractor and four Rio Tinto Iron Ore personnel have also done the training. Only 18 workplace leaders out of 100 on site have yet to do the course.

Croft says each course is attended by a vertical slice of the Weipa organisation to ensure participation in and understanding of Lean at all levels.

> *It is also an opportunity for our managers to interact, identify and resolve implementation issues.*

She notes that the mentoring role that managers have is critical to the successful application of Lean tools, coaching and helping the problem-solving process.

> *Managers have to clear away obstacles to progress and make sure that output teams get the resources they need.*

Managers are urged to be visible in the workplaces, doing regular waste walks and participating in manufacturing meetings, audits and other activities.

## Application of Lean QCO at Comalco Alumina Refinery

Although the Comalco Alumina Refinery (CAR), at Gladstone in Central Queensland, is a minerals processing plant rather than a mining operation, it is worth noting a particular application of the Lean Quick Changeover tool to a large scale project there.

The refinery is new, the first greenfield alumina plant in the world for over a generation. It was commissioned one year ago.

The refinery has two parallel enclosed digestion systems which each need to be shutdown and maintained periodically. The systems are among a number of leading edge technologies in the refinery and, consequently, few benchmarks are available.

The digesters are critical to the plant's operation and production is halved when either of the two units is shut down. Shutdowns are a massive job involving some 250 contractors on 12 hour day and night shifts.

After commissioning, the first digester shutdown took 15 days for each unit with a number of safety concerns recorded.

For the second, held in July/August this year, Lean techniques were used to manage key aspects of the shutdown with a view to making the process safer and reducing the time taken.

A project Information Centre was established, using Lean metric boards and other visual aids (see Figure 11).

FIG 11 - Daily manufacturing meeting in the Digester Shutdown Information Centre at Comalco Alumina Refinery.

Individual elements of the shutdown were managed as QCOs, with emphasis on reducing the number of tasks needed to be done with the equipment shut down.

John Sharman, Shutdown Superintendent and an employee of the contractor, Fluor Monadelphous, was impressed with the Lean application.

> *Having information visible and available was a great help,* he noted. *It gave people visual cues and they could see how they were tracking as opposed to how they thought they were tracking.*


FIG 12 - Contractors work to reconnect pipes during the digester shutdown at CAR.

Sharman had no previous experience with Lean. He noted that the shutdown involved three discrete areas of the plant and the morning manufacturing meetings served to coordinate their activities, avoiding incidents such as large deliveries arriving simultaneously.

It was decided that the two digester unit shutdowns would be programmed back to back with a one-week break between. This would keep the work team together and create a continuous learning experience.

Sharman said the strategy worked well. Additionally, a system of raising short-term and long-term concern, containment and countermeasure strips during the first unit shutdown allowed many long term issues to be dealt with during the break.

> *The system catches issues before they become critical and do harm,* he concludes.

The second shutdown was managed in 12 days for the first unit and further improved to eight days for the second unit, with no safety incidents recorded.

The savings in avoided lost production amounted to around A$3.1 million dollars compared to the first shutdown. Other QCO activities in other areas of CAR will contribute a further A$8 million during 2006 through further reducing production downtime by 30 - 50 per cent.

### Future Lean challenges for RTA

Although the Lean rollout has had positive outcomes there are significant challenges in some areas.

Lean must be integrated with other existing systems, eg health and safety, leadership training and process control.

Lean's critical challenge is for workplace leaders. The performance data is extremely public and there is potential for those who drive Lean meetings to point the finger of blame. This is counterproductive.

Our experience shows that Lean improvement requires rigorous, disciplined behaviour by managers and workplace leaders. If real cultural change is to be achieved they must devote time and effort to carrying out meaningful audits. Leaders must generally be visible in the workplace.

Some leaders struggle to make the change. This is true across the range of leadership and is common to all workplaces.

## THE NORTHPARKES MINES EXPERIENCE

*Barry Lavin, Managing Director, Northparkes Mines*

Northparkes Mines, an underground block-caving copper mining operation in central New South Wales, recently began developing the first stage of a new underground mine at its E48 project. This involves excavating 10 000 metres of tunnels using conventional drill and blast mining methods.

Reintroduction of underground development presented challenges to our project team: the development was in the middle of a highly profitable mining operation and, thus, production interruptions could not be tolerated.

Planning focused on equipment selection, scheduling and resource requirements but a myriad of operational issues plagued the initial stages of the project, resulting in constant delays and targets not being met.

The majority of issues were associated with mine services, equipment and work procedures and many of them were recurring.

With the current resources boom in Australia, procuring experienced people and suitable mining equipment has proved difficult. With development not being part of normal day-to-day operations of a block-cave mine, it became apparent that despite all the high level pre-work defining precise and elegant schedules, the skills and experience required in efficient and safe practices in the execution of common development tasks had been lost to the business and had to be rediscovered.

A solution was needed and OTX, Rio Tinto's technical division, suggested we try the Lean approach that was having success at the HVO mine in nearby Hunter Valley. Lean appeared to be a tool appropriate for the job.

Development of underground excavations follows a cyclical process that is repeated every 12 to 24 hours. The development cycle, undertaken by a crew of five or six miners, consists of:

- drilling a pattern of blastholes into the rock face;
- charging blastholes with explosives and firing;
- mucking out broken rock; and
- supporting the new section of tunnel with ground support elements including meshing, rock bolts and spray-on concrete.

Advance rates vary between three and five metres per cycle.

This was the task that Lean was called in to control and improve.

A key feature of Lean is its ability to manage a large number and variety of issues simultaneously using visual prompts to assist the communication of issues.

A Lean Information Centre was established in the project's shift change centre (see Figure 13).

The metrics that the development teams chose to track were safety, environment, employee availability, cycle completion times, weekly development targets and utilisation of resources.


FIG 13 - A Lean Information Centre at Northparkes Mines.

Their performance against these targets is reviewed every day at shift change where issues impacting performance are identified and documented.

When an issue is identified, it is noted on a concern strip in the Information Centre. The strip describes the issue; it nominates accountability for the issue; and, a target date for resolution (see Figure 14).


FIG 14 - A concern strip is raised in the Information Centre.

Issues are discussed and problem-solved in separate meetings after the shift-change but on the same day, the principal driver being that shift-change meetings should not be bogged down with problem-solving.

The concern strip is updated with containment measures that will initially mitigate the problem and countermeasures that will ultimately eliminate or resolve it.

Once any issue is resolved, it is tracked for a period to prove the effectiveness of the countermeasure. Should an issue recur it is highlighted on a pink-coloured concern strip.

The Information Centre records the progress of every concern throughout the process and provides instant feedback to development teams.

Lean has proved to be a very flexible and adaptive management tool. It is currently being used to track more than 100 issues simultaneously.

It also allows for easy communication of development rates and metrics.

This has improved communication with team leaders and crew members, who are now able to easily see where issues are occurring. As a result, crew members are more willing to contribute to identifying and solving issues that cause delays in the production cycle.

The Lean process facilitates a structured response to productivity issues, which has improved the efficiency and effectiveness of shift changes.

Overall, the benefits derived from implementing Lean Information Centres at Northparkes have been impressive, with the process contributing to a 56 per cent improvement in the cycle time within the first 30 days of adoption (see Figure 15).

They have provided a structured approach to improving productivity. The main benefits are that development targets and performance against those targets are highly visible. Development teams are actively involved in identifying and solving causes of delay.

## THE APPLICATION OF LEAN INFORMATION CENTRES AT HUNTER VALLEY OPERATIONS

*Russell Sanford, Team Leader (IPT Processing), Hunter Valley Operations*

Hunter Valley Operations (HVO), located in the Hunter Valley, New South Wales, is the largest of the seven coal mining sites that make up Rio Tinto Coal Australia.

HVO manages four open cut mines and two wash plants producing around 13 million tonnes of coal per year and is connected to a common rail system that collects product from 30 users across the Hunter Valley.

We engage around 1000 employees and contractors in fulltime equivalent positions.

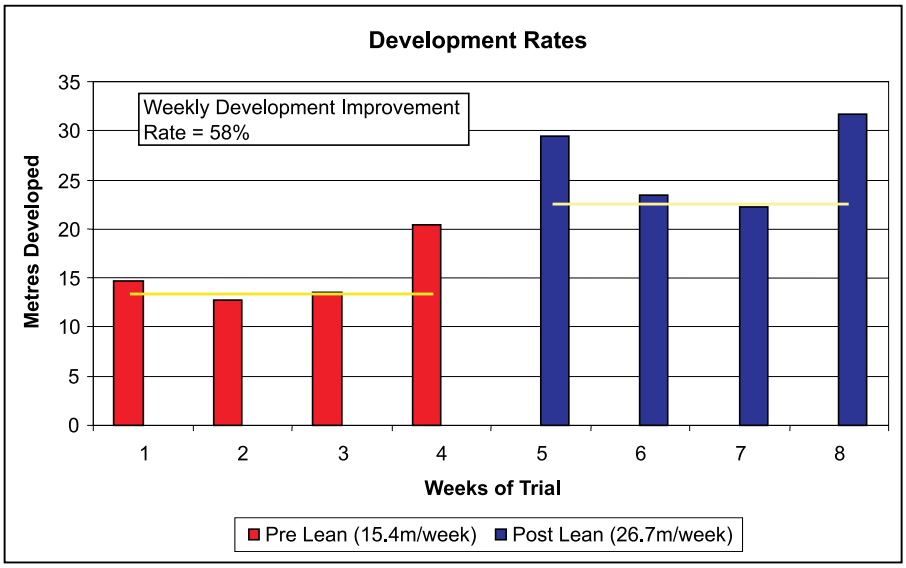


FIG 15 - Rates of development four weeks before and after implementation of Lean.

Ours was an opportunistic use of Lean dating from November 2005. We first established an Information Centre to improve the operation of one of the site's wash plants.

However, almost immediately senior managers saw that it created substantial behavioural change. There was clarity of purpose and a method of identifying and solving issues that previously did not exist.

For managers the lights went on and there was a snowball affect across the site such that, in January this year, we contracted, on RTA's recommendation, an LMR consultant, Mark Allen.

There are seven workplace Information Centres as well as a Site Information Centre where planning meetings are held, with another two currently planned for rollout in coming weeks (see Figure 16).

FIG 16 - One of the Hunter Valley Operations Information Centres.

Prior to Lean's introduction there was no forum within HVO in which operations, maintenance and planning personnel could come together to discuss issues across the mine.

The company has three operations superintendents whose roles are based on geographical areas. Maintenance superintendents have functional roles.

Because of distance and time constraints, it was impossible – pre-Lean – for superintendents to attend all the daily meetings they would need to be fully informed on issues.

Lean instituted new arrangements where superintendents attend regular meetings each day held in a central position.

They bring with them concerns, containments and countermeasures from each area with the aim of coordinating improvements across the mine.

Although these arrangements have only been in place since February, we have already experienced a dramatic reduction in the monthly variance from plan (see Figure 17). While we are not yet where we need to be, the process is clearly coming under control. We are getting there.

HVO has had an intractable problem in meeting its overburden removal targets. Managers were aware that this could be traced back to the haul truck workshop but previous efforts to solve the problems there had been unsuccessful.

Even though managers knew about RTA's positive experiences with Lean, there was initial hesitancy in applying Lean techniques to the truck workshop because of a perception that it may not be appropriate in this non-manufacturing environment. They reasoned that all it may do was confirm that we had a problem.

However, with the successful rollout of Information Centres on site and initial improvements in the workshop area, a decision was taken to rollout the Foundation Elements of Lean in the workshop to see if they could achieve incremental improvements.

We are focusing on the way operators drive trucks and the way maintainers service them, using Lean's concept of creating manufacturing teams to identify problems and find their root cause.

This has only recently started. Early signs are positive.

## CONCLUSIONS

### Rio Tinto Aluminium

Lean's power is in uniting operational and maintenance employees in purpose. It empowers people to solve problems at a workplace level and it promotes a strong sense of ownership.

These concepts are common to all workplaces and are exclusive of constraints that may be imposed by geography, isolation, work types or other factors. Thus, the core Lean values are as appropriate in a mining context as a manufacturing one.

RTA has only progressed a little way on its Lean path. However, indications are that it will continue to be an efficient and effective tool to achieve continuous workplace improvement and will play a key role in the personal skills and career development of all employees.

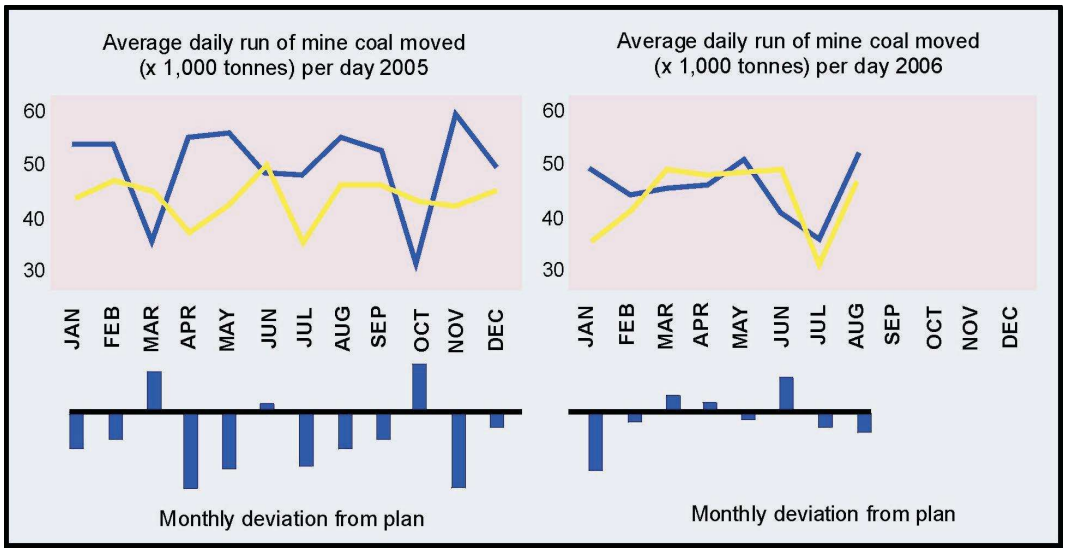


FIG 17 - Lean has contributed to a reduction in variation from plan at HVO.

A structured, organisation-wide approach to Lean ensures that improvement becomes part of a broad workplace culture in which career paths are defined, assisting in developing and retaining quality employees.

## Northparkes Mines

High level strategic planning and scheduling is meaningless unless an organisation has the skills and experience at hand to repeatedly execute the basic production tasks, safely and efficiently. In an era of high labour turnover, retention of skills within an organisation is difficult, especially for tasks that are executed only occasionally.

Lean provides a management tool through which operations can acquire or relearn the basic skills faster and in a more structured and sustained way. The approach is particularly suited to businesses that enjoy a high quality, well educated workforce, as it provides people with the opportunity and satisfaction of making a first-hand contribution to improving the business. With employees at all levels working with such focus, improvement is almost assured.

Implementation of Lean Information Centres at Northparkes has provided a significant boost to the underground development rates by providing a structured approach to improving productivity. Its main benefits are that development targets and performance against those targets are highly visible and that development teams are actively involved in identifying and solving the causes of delay.

## Hunter Valley Operations

Lean is proving that it is an appropriate business improvement program for mining applications.

While we are still in the very early days of its implementation it is rapidly being deployed at Hunter Valley Operations because managers can see that it works.

The Information Centre concept, bringing operational and maintenance employees together and ensuring that no issue raised is ignored, is a fundamentally sound approach to management.

## TESTIMONIALS

The following comments were made by people at RTA and Hunter Valley Operations. They give a good indication of Lean's acceptance at different organisational levels.

Matthew Lay, RTA Manager, Lean:

> *Lean transforms the workplace into a more satisfying place to be. People use their energy and passion to make the place better and produce something they feel pride in.*

Memo sent to Ron Jorgensen, Carbon Bake Furnace Superintendent, Boyne Smelters, RTA:

> *Subject: Proud*
>
> *To: Ron Jorgensen, Superintendent CB*
>
> *Ron,*
>
> *Makes me feel proud to be a part of the Carbon Bake team to see where we are this morning.*
>
> - *We finished the rota ahead of schedule. All four crews have pulled together to get us into this position.*
> - *With good planning and leadership it's amazing what we can achieve.*
> - *Looking forward to next week's challenges,*
>
> *Col & Steve, Crew 4*

Alan Breen, General Manager Operations, Boyne Smelters, RTA:

> *What has impressed me about Lean is that you have cross-discipline involvement in problem-solving. It tends to focus on the root cause and, from that, we come up with sustainable solutions to problems and issues.*

Peter Firth, Maintenance Superintendent, Carbon Bake Furnace, Boyne Smelters, RTA:

> *There is a feeling that we are all one team trying to produce a quality product for our customers.*

John Demos, Maintenance Crew Leader, Carbon Bake Furnace, Boyne Smelters, RTA:

> *In a short period – probably two or three weeks – we started seeing the benefits of working together. We started seeing production outputs increase. We started gaining access to equipment. There was just a general feeling of co-operation.*

Gary Mayne, LMR Consultant:

> *Lean works because it touches the heart and soul of the organisation; it touches the people at shop floor level.*

Joe Rea, Manager Carbon, Boyne Smelters, RTA:

> *The change in culture has been quite profound. The power of Lean is the tremendous involvement that it generates with every one of our people.*

Joe Riordan, Manager CHPP, Hunter Valley Operations:

> *This is the first Monday morning that we have had the specific information from the weekend, not just the numbers. The key issues are getting attended to and resolved.*

Paul Ernst, Mining Manager, Hunter Valley Operations:

> *At 9:30 every morning I can be updated on five shovels, an excavator, two draglines, and 55 trucks from three pit superintendents covering both operating and maintenance issues and it all takes only 15 minutes.*

Stephen Rogers, Line 3 Operator, Bell Bay Smelter, RTA:

> *As I became more familiar and the Drumbeat [Lean] started to kick in and work was structured that 'Hey, this is becoming much more manageable, much more relaxed', if you get what I mean. Relaxed in terms of you knew what was happening. You knew where you were going, you knew what you would be doing and you could set your own personal plan for the shift.*

Craig Anderson, Maintenance Employee, Boyne Smelters, RTA:

> *The [manufacturing] meeting is probably the best thing about Lean. It has a format; it is kept short and sharp and it helps us organise what needs to be done … It is not yet a place I would choose to spend my annual holidays but things are improving rapidly.*

Harry Haigh, Process Technician, Boyne Smelters, RTA:

> *Before Lean there was no mechanism to do these things and without that people could not trust the materials and equipment that they ordered or the quality of products being produced.*

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